Problems set 2 ... Examples taken from Van Wylen & Sonntag, 3rd Ed, pp. 425-427 and pp. 426-477 (Recommended book as a reference)

2000 ft^3 @ 14.7 lbf/in^2, 90F, 70 = ϕ
calculate: humidity ratio, dew point, mass of air and mass of vapor.

$\phi = 0.70 = \frac{P_v}{P_g}$ ← P_{sat} @ 90F from steam tables

$P_v = 0.70\,(0.6988) = 0.4892\ lbf/in^2$

Again from steam tables for saturated steam pressure table, the dew point is the saturation temperature corresponding to this pressure ~ 78.9F

$P_a = P - P_v = 14.7 - 0.49 = 14.21\ lbf/in^2$

Humidity ratio $\omega = 0.622\,(P_v/P_a) = 0.02135$

Mass a air $m_a = (P_a V / R_a T) = (14.21 * 144 * 2000 / 53.34 * 55$
$= 139.6\ lbm$

Mass of vapor can be determined from

$\omega = m_v / m_a$ $\quad m_v = \omega m_a = 0.02135\,(139.6)$
$= 2.98\ lbm$

Now if the mixture is cooled to 40F how much water vapor is condensed?

At the final temp of 40F, the mixture is in a saturated state (as 40F is below the dew point)

$P_{v_2} = P_{g_2}$ $\quad$ $P_{a_2} = P - P_{v_2}$

$\omega_2 = 0.622\,(P_{v_2} / P_{a_2})$

Mass of vapor condensed $= m_a(\omega_1 - \omega_2)$

(Note, mass of air is not changing, and $P_{v_2} = P_{g_2}$)
when $P_{g_2} = P_{sat}$ @ 40F)

$P_{v_2} = 0.1217\ \text{lbf/in}^2$ $\quad$ $P_{g_2} = 14.7 - P_{v_2} = 14.58$

$\omega_2 = 0.622\,(0.1217 / 14.58) = 0.00520$

Mass of vapor condensed

$= m_a(\omega_1 - \omega_2) = 139.6\,(0.02135 - 0.0052)$

$= 2.25\ \text{lbm}$

Methane CH_4 is burned with atmospheric air. Dry basis products yield

$CO_2 = 10\%$ $O_2 = 2.3\%$ $CO = 0.53\%$ $N_2 = 87.1\%$

Calculate A/F ratio and % theoretical air.

First write generalized combustion equation in the form

$$a\,CH_4 + b\,O_2 + c\,N_2 \Rightarrow 10.0\,CO_2 + 0.53\,CO + 2.37\,O_2 + d\,H_2O + 87.1\,N_2$$

Note that we assume for this analysis that we will build a one-step reaction based on dry product yield ... of course we need to determine how much H_2O is present to write the combustion equation

For nitrogen: No oxides of NO $\therefore$ $c = 87.1$

We know that the ratio of N_2/O_2 in the air is about $79/21 = 3.76$ $\therefore$ $c/b = 3.76$

$b = 23.16$

From the carbon balance $a = 10.0 + 0.53 = 10.53$

~~Dividing~~ We can now write the normalized combustion equation (÷ by ↑)

$$CH_4 + 2.2\,O_2 + 8.27\,N_2 \Rightarrow 0.95\,CO_2 + 0.05\,CO + 2\,H_2O + 0.225\,O_2 + 8.27\,N_2$$

$$10.53\ CH_4 + 23.16\ O_2 + 87.1\ N_2$$
$$\rightarrow 10.0\ CO_2 + 0.53\ CO + 2.37\ O_2$$
$$+ 21.06\ H_2O + 87.1\ N_2$$

(This is the equation which we divided by 10.53 to get the combustion equation base on 1 mole of fuel)

Air-Fuel ratio on a mole basis is

Fuel 1 mole   Air (2.2 mole O_2 + 8.27 mole N_2 = 10.47 moles air)

ON A MASS BASIS

$$AF = (10.47 \times 28.97) / 16.0 = 18.97 \frac{kg\ air}{kg\ fuel}$$

Theoretical A/F ratio ... First write comb. equation for theoretical air

$$CH_4 + 2O_2 + 2(3.76)N_2 \rightarrow CO_2 + 2H_2O + 7.52\ N_2$$
$$(A/F)_{Theoretical} = (2 + 7.52)(28.97)/16 = 17.23 \frac{kg\ air}{kg\ fuel}$$

$$\therefore \%\ \text{Theoretical air is} = \frac{18.97}{17.23} = 110\%$$